BNFL Inc.

Section 2.8

Unit Operations

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BNFL Inc.

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Unit Operations

2.8.1. Canister/Container Handling

The facility has a canister handling line for high level waste (HLW) product and container handling line Low Activity Waste (LAW) product.

2.8.1.1. Purpose

The purpose of the Product Canister/Container handling lines is to deliver canisters/containers to the various work stations. The product canister/container goes through the following work stations: filling and lidding, welding, decontamination, swabbing and monitoring and finally, storage. The purpose of these work stations is to have a confined and clean product located in a store.

2.8.1.2. Description

The movement of the canister/container to the various work stations will be achieved by the use of systems and equipment described in the mechanical section of this document (e.g., in-cave cranes and in-cave trolleys). The work station functions are indicated by their titles. Two of the stations have safety issues--decontamination and swabbing--and so are described briefly below.

2.8.1.2.1 Decontamination

Vitrified product packages produced at the Hanford site will be of two distinctly different specifications. The LAW product canister will be large rectangular stainless steel boxes and the HLW product will be long, narrow, cylindrical, stainless steel canisters. A number of potential canister/container decontamination processes are being considered for the TWRS-P project. These are presently being reviewed in order to identify which process(es) compare best against contract and design requirements for these LAW container and HLW canister designs. It is possible that different processes will be selected for LAW and HLW product canisters.

One of the processes being considered is the decontamination process used at the BNFL HLW vitrification plant in the UK. BNFL places its contaminated vitrified product canisters in a decontamination booth and uses ultra high-pressure water to decontaminate the canisters. This process consists of an ultra high-pressure water wash and an effluent collection and transfer system. An out-of-cell supply of demineralized water is pumped through a reverse osmosis filter to remove any material that would block or abrade the high-pressure water nozzles. The water pressure is boosted in a hydraulic pressure intensifier to around 36,250 to 58,000 psig and then sprayed through a series of nozzles onto the canister surface. This ultra high-pressure wash effectively removes surface contamination from the canister. The wash effluent is collected in a base tray which drains to a dedicated catch vessel. The catch vessel contents are periodically discharged to an effluent collection vessel for treatment and disposal. Following decontamination, the canister is posted out of the spray booth to an adjacent cell for swabbing/monitoring. Clean product canisters are then moved into the vitrified product store. Canisters that fail to meet the product store acceptance criteria are posted back into the decontamination cell for further treatment. When further decontamination is required, the ultra high-pressure jets may be focused upon a specific area, and the operating parameters adjusted to increase the cleaning power.

2.8.1.2.2 Swab and Monitor

The product canister/container will be set up on a turntable and set rotating in a dedicated cave. A robotic arm mounted in the cave then picks up a "clean" swab and brings it into contact with the container. The robotic arm then moves the swab over the surface of the container in a predetermined pattern. Once the required surface has been "swabbed," the swab is placed into a carrier (small plastic cylindrical container) and this placed in a transfer system. The transfer system performs a monitor of the swab as it leaves the shielding of the cave. The swab is then diverted into a high reading collection bin which will have shielding or a "pass" bin which will not require shielding. If the result is within the required limits of a pass, then the container is cleared for export. If the result is above the limits of a high reading, then the container will be returned for further decontamination.

2.8.1.3 Hazardous Situations

Reviewing the systems against the end purpose the following hazards are identified.

1. The outside of the canister/container is contaminated and this is spread through the plant to the store.

2. The swabbing system could export a "highly" active swab thus increasing operator dose.

3. Potential for aerosol/mist (from contact of ultra high-pressure water with product canister) escaping from the decontamination booth into the cell, increasing the challenge to the cell vent system (C5).

4. Potential for cross-contamination in condenser (heat exchanger).

5. Container washings catch vessel steam ejector—continued steam delivery after vessel is empty.

Figure 2.8-1. Typical Cave Layout for Remote Operations.

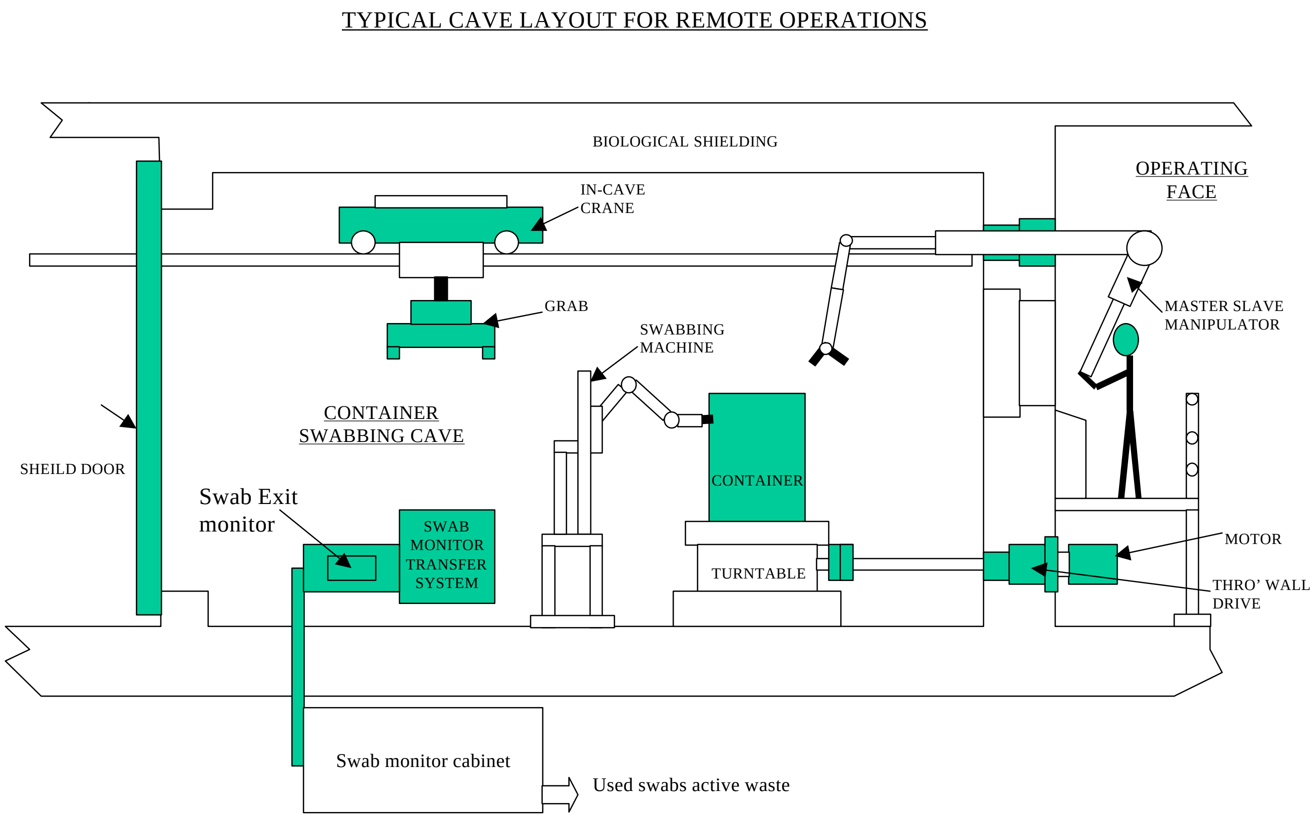

Figure 2.8-2. Container Decontamination

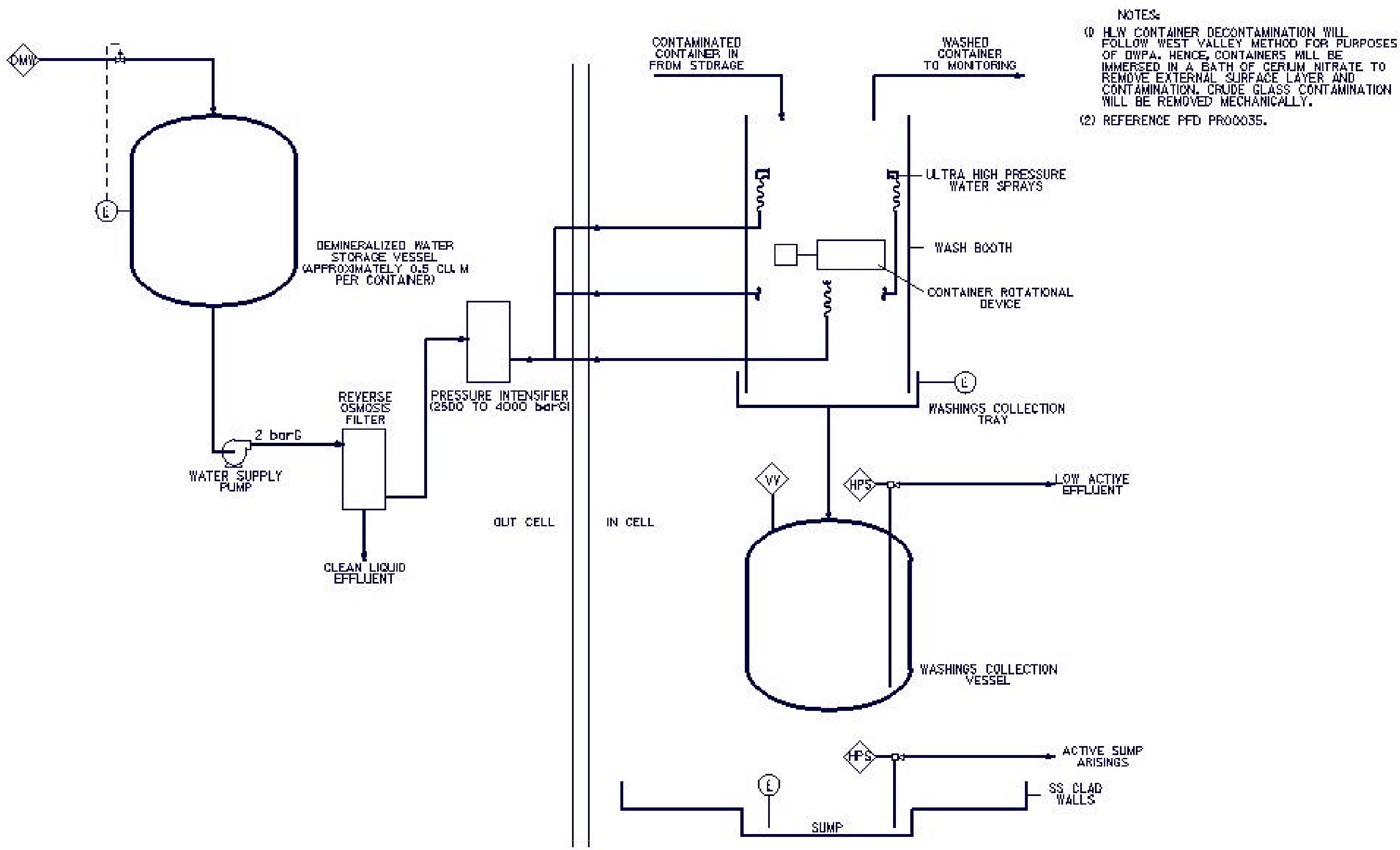

Table 2.8-1. Canister/Container Handling

Canister Handling			
Fault	**ITS SSC**	**Safety Function**	**Design Safety Feature**
Transfer of Contaminated Container results in spread of contamination	Swabbing and Monitoring System	Prevent posting out of contaminated container.	Design of containers provide for ease of decontamination.
Loss of control of "high"-radioactive swabs from caves	Monitor and diverter on delivery system.	To control removal of high-radioactive swabs from cave.	Initial testing and periodic functional testing and fail safe alarm on radiation monitor.
Decontamination System			
Container decontamination (BNFL Sellafield example)			
Radioactive aerosol/mist from contact of water with product canister escapes into cell challenging cell ventilation system (C5).	Booth	Prevents escape of aerosol/mist into cell.	Booth seal designed to prevent escape of aerosols/mists when closed. Test booth performance during cold testing.
	Booth closure instrumentation and interlocks Booth seal designed to prevent escape of aerosols/mists when closed	Prevents use of ultra high-pressure pump when booth is not sealed closed.	Factory test. Test interlocks on plant during commissioning. See Section 2.4 "Instrumentation and Control." Duplicate instruments.
Cross contamination in condenser (heat exchanger)	Cooling water system piping	Maintain integrity	See Section 2.1.1 "Vessels" Loss of contamination control. See Section 2.12 "Piping."
Container washings catch vessel steam ejector – continued steam delivery after vessel is empty results in a challenge to the ventilation system	Temperature Instrumentation	Detect steam break-through and isolate ejector	See Section 2.6.3 "Steam Ejectors."

2.8.2. Evaporator

The facility has four evaporators: LAW Feed Evaporator, LAW Melter Feed Evaporator, Cesium Nitric Acid Evaporator, and Technetium Evaporator. The first two evaporators are discussed in this section. The other evaporators are pot evaporators and are described in Section 2.8.7, Nitric Acid Recovery.

2.8.2.1. Purpose

The primary purpose of the low activity waste (LAW) melter feed evaporator system is to concentrate the feed to the LAW melters. Concentrating the feed will decrease the heat burden of the LAW melters, will decrease the size of the LAW melter feed buffer tanks, and will decrease the volume of offgas being treated by the LAW melter offgas treatment system.

The LAW melter feed evaporator systems will also be designed to concentrate the solutions to the highest extent possible without having a negative impact on the evaporator or any downstream equipment/ systems. The key constraints to the degree of evaporation are the solubility limits of the concentrate and the ability of the melter feed system to distribute the feed to the melter.

The primary purpose of the LAW feed evaporator is to concentrate the LAW feed from DOE for processing in ultrafiltration and ion exchange. This concentration reduces the size of the ultra-filter bank and produces a consistent feed for ion exchange. The constraint on concentration by this evaporator is the downstream process requirements.

2.8.2.2. Description

The main process components of the TWRS-P evaporator systems comprise the evaporator, heat exchanger (evaporator reboiler), circulation pump, overhead vacuum system, vapor condensers, product receipt vessel, and condensate holding vessel. Other equipment include a Constant Volume Feed, RFD's, steam ejectors, and flow control valves.

Evaporator feed is sampled to determine the optimum amount of evaporation desired before being fed to a constant volume feeder that controls the feed to the LAW melter feed evaporator vessel. The evaporator vessel itself is operated continuously under a vacuum and the heat is added via the low-pressure steam system to an evaporator reboiler. Sufficient hydrostatic head is maintained to suppress the boiling point inside the reboiler. The hydrostatic head diminishes and flash evaporation occurs as the flow enters the evaporator vessel itself. The liquid continues to flash to equilibrium and the vapor and liquid streams are separated. The liquid stream continues to circulate in this closed loop (becoming more concentrated), while the vapor stream passes to a condenser.

The resulting vapor from the condenser is routed through a series of steam ejectors and heat exchangers before entering an after condenser. The steam ejectors and heat exchangers are employed to create the vacuum condition in which the evaporator operates. The resulting vapor stream from the after condenser is routed to the vessel vent system. The condensates from the condensers and heat exchangers are routed to a collection vessel before being sent to the condensate drain system.

The concentrated LAW product from the LAW Feed Evaporator is collected in a concentrate hold vessel where it is sampled prior to ion exchange treatment to remove cesium. The concentrated LAW product from the LAW Melter Feed Evaporator is collected in a concentrate hold vessel where it is sampled prior to vitrification.

2.8.2.3. Hazardous Situations

Hazards associated with the normal operation of the evaporator include those of confinement associated vessels, addressed under vessels, that of cross contamination of utilities (process water, chilled water, steam), addressed under the individual systems and those particular to the system for which protection is provided. Known fault conditions against which protection is required are:

- Introduction of liquid into vent system from overfilling of product receipt or condensate tank
- Introduction of liquid into vacuum system from overfilling of evaporator
- Contamination of overhead condensate lines due to excessive aerosol or liquid contamination
- Plugging of feed line an operational consideration for downstream systems. No identified safety hazards
- Challenge to ventilation from over boiling
- A common concern for evaporators in nuclear service is the danger of “Red Oil.” This compound can be produced only when the following conditions occur: high nitric acid concentrations, high heavy metal (e.g., U, Pu) concentrations, free-phase organic compounds (e.g., tributyl phosphate, normal paraffin hydrocarbon), and high temperatures (>120^{o}C). While it is feasible that free-phase organics may enter the TWRS-P feed systems (with HLW from C-106 or C-103), the current design temperature of the evaporators is 50 °C and the distribution of strong nitric acid is limited to the production of 0.5 M acid by a series of controlled dilutions. This diluted (0.5 M) acid is added to the nitric acid recovery systems' storage tanks to make up acid consumed during elution processes and this recovered acid is only used after sampling. In addition, none of the process stream contains heavy metals in the concentration required. Hence, the production of “Red Oil” is not considered to be a feasible occurrence for the current TWRS-P design.

  A further consideration is the HAR was the potential for ventilation collapse due to vacuum. The original HAR comment is not valid for the following reasons. The motive steam, air and flash steam/water vapor that is extracted from the evaporator recirculation vessel is cooled in water cooled condensers, the liquid condensate is collected and removed, the cooled air is discharged at a positive pressure into the vessel vent system via a demister pot. As long as motive steam is fed to the ejectors there is a positive flow of air into the vessel vent system. If the steam supply fails with full vacuum in the evaporator then the vacuum will try to pull against the open vessel vent system and fans and would have to evacuate the full length of vessel vent system before any physical impact could be felt by the pipework.

Figure 2.8-3. Evaporators

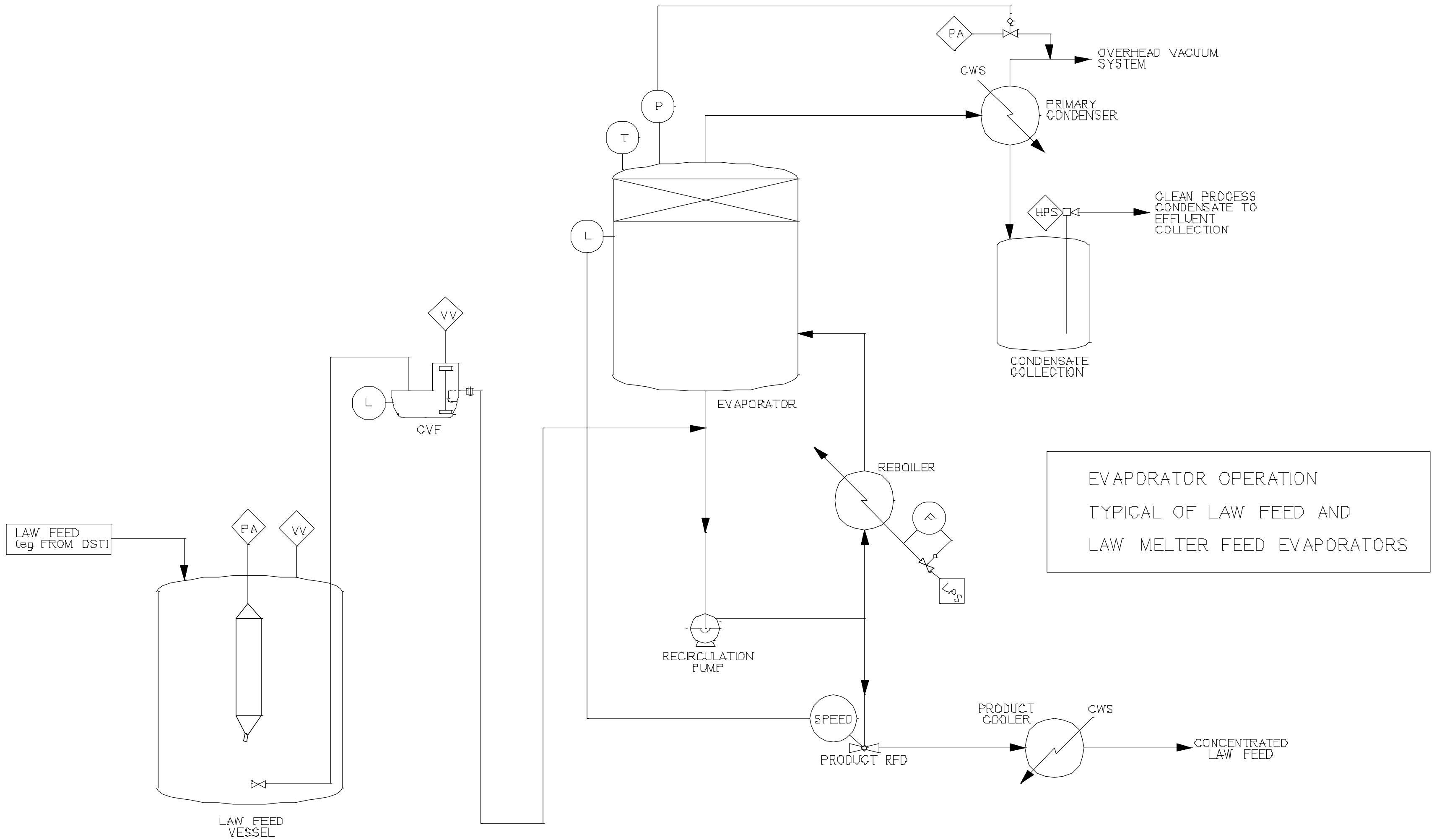

Table 2.8-2. Evaporator

Fault	ITS SSC	Safety Function	Design Safety Feature
Introduction of liquid into vent system (overfilling of product receipt or condensate tank)	Level measurement/ trip	Alarm on overfilling	Diverse measurement systems Alarm/Trip on measurement System see Section 24.5 "Instrument and Control Design Safety Features."
	Vessel Vent System	Prevent migration of liquid into vent system	Hydrostatic positioning will be given due consideration for all vessel vent lines in order to prevent liquid from entering the system.
Introduction of liquid into vacuum system (overfilling of evaporator)	Level measurement /trip	Alarm on overfilling	Diverse measurement systems Alarm/Trip on measurement System see Section 24.5 "Instrument and Control Design Safety Features."
	RFD (to product tank)	Control level on rate on which product is drawn off	
	Vacuum Overhead System	Prevent migration of liquid into vacuum system	Hydrostatic positioning will be given due consideration for all vessel vent lines in order to prevent liquid from entering the system.
Contamination of overhead condensate lines due to excessive aerosol or liquid contamination	Beta/Gamma detectors on condensate lines	Detect contamination in condensate line	Calibration/maintenance
	Flash chambers	Provide Flashing of steam without carryover of concentrate	Flash chamber inlet located above maximum liquor level (also see overfilling of evaporator above).
	Demister	Knock out aerosols	Provision for washing demister
Plugging of feed line No identified safety hazards. Operational consideration.	Freeze valves High Pressure Water Wash	Isolate feedlines and provide for high-pressure water wash to clear obstruction	Lutes will be fitted with freeze valves and water flush capability in order to clear any potential line blockages
Challenges to vessel ventilation from overboiling	Temperature control system / trip	Control evaporator operating temperature and degree of boiling by regulating steam supply to reboiler	Temperature system fails high and shuts off steam supply to reboiler and removes source of heating. The original HAR comment is not valid. Refer to Instrument & Control DSFs
Ventilation collapse due to vacuum			

2.8.3. Pulsejet (Fluidic) Agitators

2.8.3.1. Purpose

Pulsejet agitators are used throughout the TWRS plant to provide resuspension of solids and to provide well dispersed mixtures prior to sampling of process liquors. They are used in preference to conventional mechanical agitators in radioactive areas because they do not have moving parts to maintain within cell.

2.8.3.2. Description

The agitator system works on the principle of raising and lowering the process fluid within a tube located within the process vessel. This action imparts movement into the process fluid. Details are shown in Figure 2.8-4.

The system consists of a number of tubes that are dipped within the process vessel. The tubes are fitted in a circular fashion around the inside of the vessel. The bottom of the tubes is tapered to form a nozzle. The other end of the tube is connected to a pair of jet pumps. The jet pump pair provides the suction for drawing liquid up the tubes and provides the exhaust to drive the liquid back down the tubes. The operation of the jet pump pair is similar to the ones used for the reverse flow diverters. There are two phases in the cycle, namely suction phase and drive phase.

Suction phase: A secondary automatic valve is open, admitting air to the suction jet pump. Liquor is sucked from the vessel through the nozzle and into the agitator tube. The suction ejector is designed so that it cannot produce a vacuum capable of lifting liquor higher than a certain value known as the "suction lift". After a short time the liquor reaches this height and stops and the valve is shut.

Drive phase: The next operation is that the suction valve is shut admitting air to the drive nozzle. Air passes through the nozzle and pressurizes the agitator tube. Liquor is forced down the agitator tube into the vessel. When the agitator tube is nearly empty the air supply is turned off. The compressed air in the agitator tube passes back through the jet pump pair, down the vent pipe and into the vessel vent system.

2.8.3.3. Hazardous Situations

Normal operation of a pulsejet agitator does not require the achievement of any particular safety function beyond utility confinement. A cabinet is provided to house the air handling system to achieve this. A number of fault conditions can however place demands on other ITS SSCs. Known fault conditions against which protection is required are:

- **Overblow:** Air is blown through the process liquor causing enhanced aerosol challenge to the vessel ventilation system.

- **Oversuck:** Air is sucked through the liquor in the agitator tube causing enhanced aerosol challenge to the vessel ventilation system.

- **Over-raise:** The suction phase lifts liquor out of shielding and primary confinement.

- **Crossblow:** Liquor is pulled into one jet pump and an air liquor mixture expelled from the other, causing enhanced aerosol challenge to the vessel vent system.

Figure 2.8-4. Typical Arrangement of A Pressure/Suction Fluidic Agitator

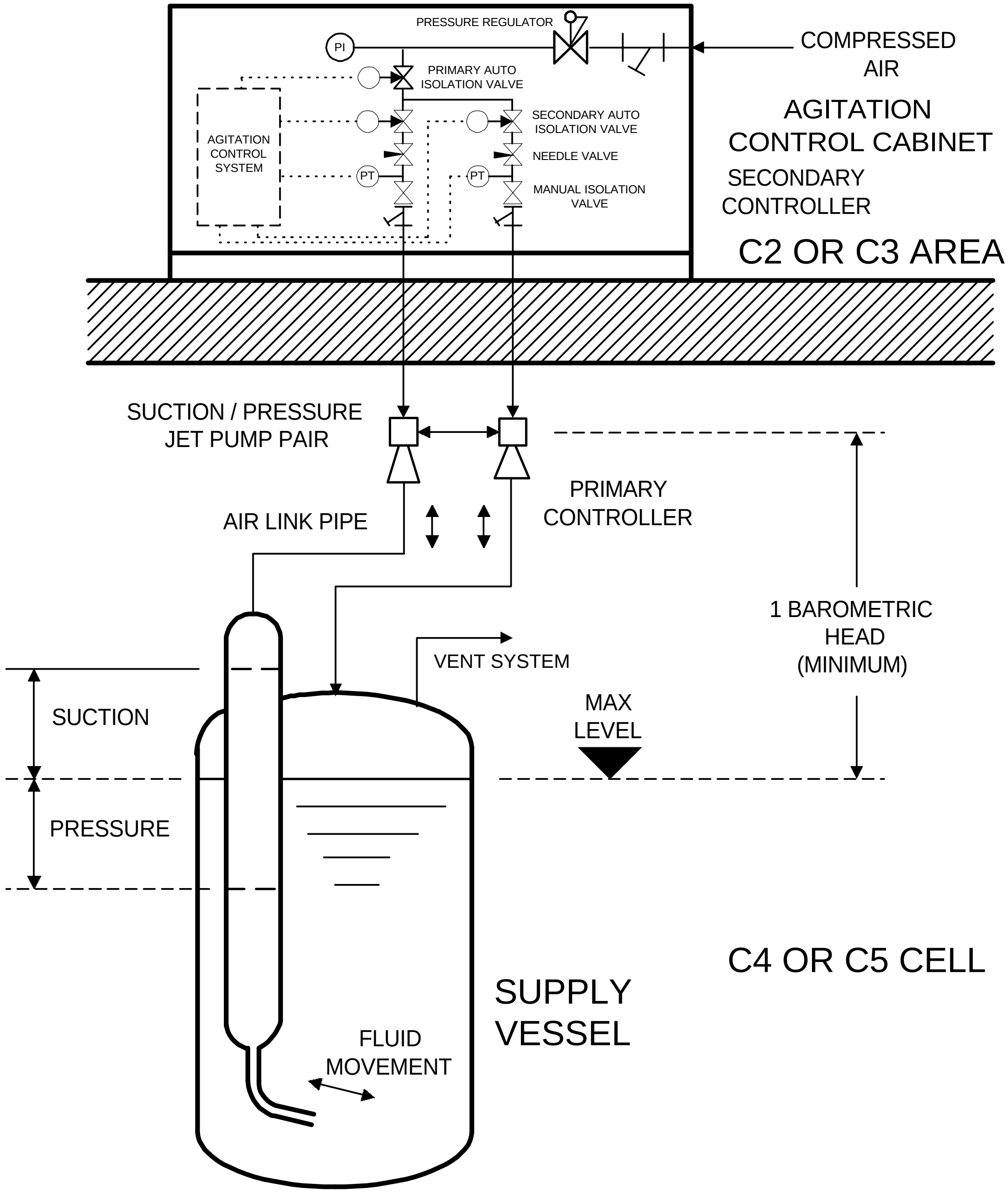

Table 2.8-3. Fluidic Agitators

Fault	ITS SSCs	Safety Function	Design Safety Feature
Overblow. An excessive drive phase can lead to air being blown through process liquor causing aerosol challenge to vessel ventilation system scrubber and filters.	Timers and/or pressure controllers. The controller monitors pressure/time relationships and thus terminates drive and suction phases optimally. Its use is not certain and if used it would provide additional protection to that outlined for the timer system which is assumed.	To terminate drive phase before overblow	Alarm on excessive time
	Drive valve	To close on demand	Fails closed on loss of operating power
	Pressure regulator	To deliver pressure no greater than assumed in timer set-up	Regulator is locked in position after set-up Alarmed pressure transducer reveals deviation
	Needle valve	To regulate flow to no greater than assumed in pressure and drive time set up	Needle valve is locked in position after set up.
Oversuck. Normal suction phase with vessel at low level can cause aerosol generation within the pulse tube resulting in a blow out through jet pump pair. This ultimately challenges the vessel vent system scrubber and filters.	Level measurement in vessel	To terminate suction phase before level low enough for oversuck	Alarm on low level
	Suction valve	To close on demand from level instrument	Fails closed on loss of operating power
	Primary isolation valve	Close on low vessel level. Isolates air to system to avoid overblow on next cycle	Fails closed on loss of operating power.

Table 2.8-3. Fluidic Agitators

Fault	ITS SSCs	Safety Function	Design Safety Feature
Over-raise of active liquor out of primary shielding and confinement is not possible due to the location of the jet pump pair within the cell. Also the location of the pumps above the liquor is more than the maximum lift height they can generate	Position of jet pumps within cell	Maintain shielding and primary confinement	Design and construction change control. Installation checking of locations
Crossblow. Liquor is pulled into one jet pump and air liquor mixture blown out through the other causing increased aerosol challenge to the vessel ventilation system	Suction jet pump	Sized to be incapable of raising liquor into pump at maximum air flowrate. This is done by barometric head if possible, but if not depends on air flow and pressure control	Set by design Tested during commissioning
	Pressure regulator	To deliver pressure no greater than used in commissioning setup	Regulator is locked in position after set-up Alarmed pressure transducer reveals deviation
	Needle valve	To regulate flow to no greater than used in commissioning setup	Needle valve is locked in position after set up.

2.8.4. High-Level Waste Melters

2.8.4.1. Purpose

The purpose of the melter system is to convert blended waste and glass formers into molten glass. The glass formers are received from the glass former handling facility as a dry powder mixture. The glass forming chemicals and the waste concentrate are mixed to the melter feed slurry in the feed preparation vessel and transferred into the melter feed vessel. The slurry is then continuously metered into the top of the melter. The molten glass is cast into canisters where it cools to form a durable glass waste form.

The melter system consists of the feed tubes, and other components which enter the melter cavity through the top (temperature sensors, level detector), the melter vessel itself, and the discharge systems.

2.8.4.2. Process Description

The operating temperature of the molten glass pool within the melter is nominally 1,150 ^{o}C (2,102 ^{o}F). In the melter, the feed flows across the molten glass surface and forms a cold cap on the surface of the melt. In the cold cap, water is evaporated from the feed and released to the off gas system as steam. The nonvolatile feed components then undergo chemical reaction, decomposition and are dissolved into the molten glass pool. New slurry is introduced to the melter at approximately the same rate as the cold cap dissolves, thus establishing a steady inventory of cold-cap material.

During the decomposition process, gases are formed and released into the melter plenum and drawn into the off gas system. In addition to the gases, a fraction of the feed components is directly carried over to the off gas without incorporation in the glass. The solids and semi-volatile components captured by the off gas system are recycled back to the melter to increase the incorporation rate in the glass.

Glass is discharged from the melter via one of two discharge chambers. Two chambers are provided for redundancy. Discharge is achieved by transferring glass from the bottom of the melter pool through a riser into a discharge chamber for pouring into a canister. The glass is then allowed to cool, forming a highly durable boro-silicate glass waste form.

2.8.4.3. Description

The melter is a Joule-heated, refractory-lined rectangular vessel with an outer steel shell (Figure 2.8-5). The melter can be described as three compartments: glass tank, discharge chambers, and plenum.

The tank is lined with refractory material designed to withstand corrosion by molten glass. The refractory package serves as a mechanical, thermal, and electrical barrier between the molten glass inside the melter and the metal shell. The glass tank area is fitted with water cooling to maintain a thermal gradient in the bricks to slow corrosion, stop migration of glass through the bricks, and reduce heat load to the process cell. The refractory package is designed so that even without water cooling, the glass will be contained within the tank.

The melter is heated by passing electrical current through the molten glass pool between metal electrodes on the sides and bottom of the tank. The electrodes are fabricated of a material designed to withstand the corrosive molten glass environment. Power is provided to the electrodes by large bus bars which pass through the tank walls.

There are two discharge systems for redundancy. The discharge chambers surround the discharge troughs through which the glass flows from the discharge riser to the product canister. The discharge chambers are insulated and electrically heated in order to keep the glass hot while it runs down the trough and until it falls by gravity into the canister.

The plenum is the headspace above the glass tank and is lined with refractory to withstand hot corrosive gases, thermal shock, and glass splatter. The melter lid, which is also refractory lined, forms the top of the melter. The lid supports several components such as temperature sensors and the level detector, which enter the melter chamber through penetrations in the lid. There are also penetrations for feed tubes and the offgas line.

The overfilling of a container from the discharge systems is not currently viewed a safety issue as the glass will be contained in acceptable areas. However, this could represent a major recovery problem and so it will have an interlock system which will stop discharge on the high-level alarm.

2.8.4.4. Hazardous Situations

The possible hazardous situations for a waste melter are that significant amounts of molten glass is released to the melter cave, that significant amounts of gasses from the melter are released to the melter cave, and that considerable heat radiates from the melter to surrounding equipment and the cave. These hazardous situations may challenge the ventilation system or the surrounding structures of the cave.

The hazardous situations associated with melter operation include:

- Glass leak from primary confinement.
- Glass discharge without canister or container in place.
- Over feed to melter causing melter to over flow.
- Plenum gases being released into the cell from over pressurization.
- Excessive heat released from the melter to the cell.

During the hazards evaluation of part A, the potential for a steam explosion resulting from an injection of water into the melter was considered. The melter conditions are such that the viscosity of the glass is too high to provide sufficient injection of water into the glass. However, the potential for molten glass with a lower hazardous viscosity was classed as an open item.

Steam explosions can occur when one liquid is brought in contact with a second liquid that is hot enough to cause film boiling. Steam explosions have been produced in the laboratory with molten saltwater systems, but not molten glass water systems. The fragmentation and intermixing necessary to generate a steam explosion also require the interface temperature, upon contact of the two liquids, to exceed the spontaneous nucleation temperature.

An analysis of the Defense Waste Processing Facility slurry-fed melter by Hutcheson, et al., of Fauske & Associates 1983, found that the conditions in a slurry-fed melter prevent a steam explosion from occurring. The viscosity of the glass melt was too great to permit significant water intermixing, thereby retarding any escalation to an explosion. There were no identified external triggers in the DWPF system to cause introduction of water onto a molten salt layer (that may form on top of the molten glass) results in a surface interaction which displaces the molten salt, rather than leading to a large-scale interaction.

Figure 2.8-5. High-Level Waste Melter Schematic

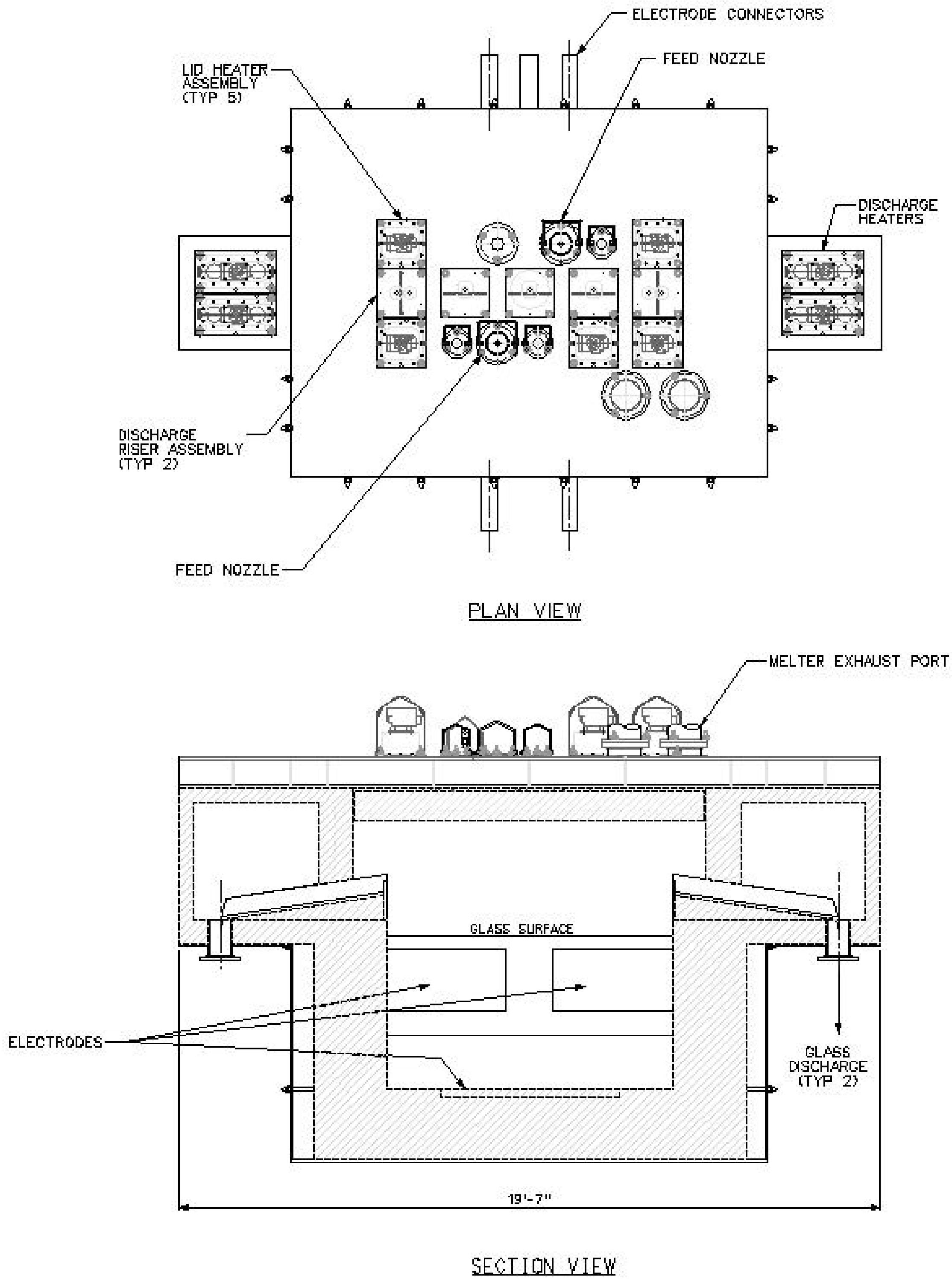

Table 2.8-4. Melter

Fault	Important to Safety SSC	Safety Function	Design Safety Functions
Glass leak from melter primary confinement initiated by: - excessive glass temperature and time of operation.	Administrate controls and trend monitoring	Prevent release of glass from melter to melter cave.	Refractory thickness The failure of the melter from excessive glass temperature and extended use are both long time frame faults, i.e., the temperature must be raised for weeks before refractory failure could occur. The prototype will provide information for the detailed design and conformation of this approach. For Defense in Depth The normal control system will take multiple glass temperature readings taken throughout glass pooling and trend the temperature instrument outputs. Periodic replacement and calibration of temperature instruments The cave and ventilation systems provide mitigation if a leak occurs
- Glass discharge without container at fill position	Positional interlocks for the container in place	Prevent release of glass from melter to cave	Interlock design; see CE&I section 2.4.5 “Instrument and Control Design” For Defense in Depth The normal control system will monitor the position and state of the containers The cave and ventilation systems provide mitigation if a leak occurs
- Overfeed melter causing glass to over flow	Level interlock for feed stream	Prevent release of glass from melter to melter cave	Interlock design; see section 2.4.5, Instrument and Control Design For Defense in Depth The normal control system will monitor the level of the glass pool. Periodic replacement and calibration of the level instruments. The cave and ventilation systems provide mitigation if a leak occurs.
Plenum gases released to cave environment by overpressurization	Melter offgas system and stand-by offgas system	Prevent release of gases from melter to melter cave.	See section 2.2.3 LAW/HLW Melter Offgas and Vessel Vent System.

Table 2.8-4. Melter

Fault	Important to Safety SSC	Safety Function	Design Safety Functions
Excessive heat dissipation from melter to the melter cave challenging the HVAC system and cell structure.	Cooling system temperature control	Reduces heat given off by melter to within acceptable limits.	Interlock design; see section 2.4.5, Instrument and Control Design For Defense in Depth The normal control system will monitor the cooling water temperature and flow rates The cave and ventilation systems provide some capacity for heat dispersion

2.8.5. High-Level Waste Receipt and High-Level Waste Pretreatment

2.8.5.1. Purpose

The high-level waste (HLW) feed receipt system serves a variety of roles depending on the time it is in service.

1. Initially, it will receive the HLW slurries from the DOE prior to pretreatment; feed the ultrafiltration system and will store the pretreated HLW solids from HLW Pretreatment. Later the system will provide the additional service of lag storing the separated strontium / TRU solid streams from LAW pretreatment prior to blending it with the HLW vitrification feed.

2. HLW feed, consisting of Envelope D solids and Envelopes A, B, or C liquids will be fed to the HLW Feed Pretreatment System. Here processes separate the envelopes, wash the solids, and, if deemed necessary, treat (hot caustic wash) the solids. The separated Envelope A, B, or C will be combined with the wash/treatment streams and routed to LAW pretreatment. The treated solids will be routed to the HLW Feed Receipt System for storage.

3. When HLW vitrification is available the solids will be transferred to a blending facility where they will be combined with Cs, Tc, and strontium/TRU streams from LAW pretreatment and routed to the HLW melter.

2.8.5.2. Description

2.8.5.2.1. Receipt

The initial feeds from the DOE will be from 241-AZ-101 and 241-AZ-102. The first feed batch will be 600 m^3 with the additional batches being between 200 m^3 and 400 m^3. A total of 830 m^3 pretreated HLW solids will be stored at 25 wt% (approximately 50 volume percent) solids. Between the start of HLW vitrification and the start of LAW vitrification operations, HLW Receipt may continue to receive additional batches of HLW feed; store the treated HLW solids; feed the HLW vitrification system, and receive recycle streams from HLW vitrification. The pretreated HLW solids will continue to be stored during this time.

During later phases of operation, HLW Receipt will receive additional batches of feed from the DOE up to the maximum order quantity. The system will also continue to provide lag storage for the pretreated HLW solids (as needed) and will feed the HLW vitrification system. In addition to this, the system will provide lag storage for the strontium/TRU products from LAW pretreatment operations. The amount of lag storage volume required and the timing of the lag storage needed will depend on LAW pretreatment alone. The four primary functions of HLW Receipt are to:

- Receive and lag store HLW feed from the DOE
- Lag store HLW solids from HLW Pretreatment
- Blend the HLW feed with HLW vitrification recycle streams
- Lag store HLW solid streams from pretreatment in support of LAW vitrification

To carry out these functions, the system will also:

- Sample process streams
- Receive streams from internal systems
- Lag store streams from internal systems
- Monitor system
- Contain the waste

2.8.5.2.2. Pretreatment

HLW Pretreatment consists of two parallel ultrafilter circuits each containing one ultrafilter. During operation, only one circuit will be online at one time. HLW feed will be routed from HLW Receipt to the HLW ultrafiltration feed tanks in HLW Pretreatment. The size of the transfer will be limited to the size of the feed vessel or to one days worth of HLW feed after treatment. Permeate from the ultrafilter will collect in the permeate collection vessel and concentrated solids will collect in the ultrafilter feed vessel. If additional treatment of the solids is warranted, this washing would occur in the ultrafilter feed vessel and the solids would be concentrated via the ultrafilter circuit. The resulting treated solids are routed to HLW Receipt for storage. From HLW Receipt the solids are routed back to HLW Pretreatment into the HLW feed blending vessels. In the blending vessels, the treated HLW solids are combined with the concentrated Cs/Tc streams and the Sr/TRU solids from LAW pretreatment before being routed to HLW vitrification. The three primary functions of HLW Pretreatment are:

- Separate solids from liquids (the removal of the low level portion (liquid) from the high level portion (solids). This includes the initial separation of the Envelopes A, B, or C from the Envelope D as well as the separation of the liquid wash/treat portion from the HLW solids).

- Treat the separated solids (solids washing as well as the addition of chemicals to “dissolve” selected components present in the HLW solids).

- Blend wastes to HLW vitrification (blending of the treated HLW solids from HLW Pretreatment with the HLW streams from LAW pretreatment (Cs/Tc eluate from ion exchange and Sr/TRU solids from LAW feed pretreatment).

To carry out these functions, the system will also:

- Sample process streams
- Chemical additions
- Store intermediate products
- Blend HLW feed
- Monitor system
- Contain the waste

2.8.5.3. Hazardous Situations

1. Overfilling and subsequent introduction of fluid into the vessel vent system.

2. Backflow of activity into cabinets. (Influent lines to particular vessels will be valved or luted to guard against backflow).

3. Loss of confinement and potential increase in activity release to environment.

4. Self-heating of receipt vessel contents leading to extra burden on vessel vent system.

Figure 2.8-6. High Level Waste Receipt and High Level Waste Pretreatment

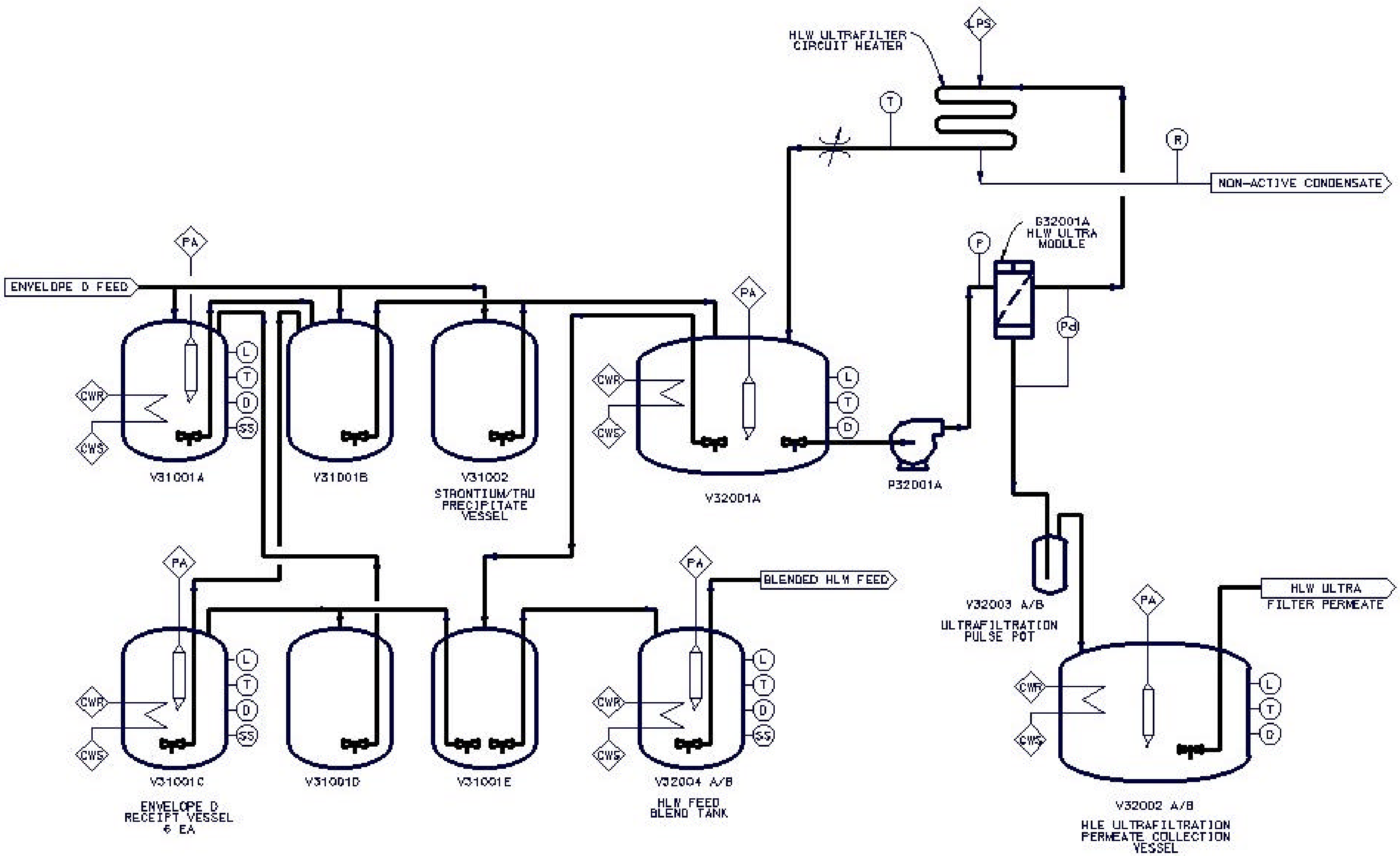

Table 2.8-5. Pretreatment

Fault	ITS SSC	Safety Function	Design Safety Feature
Overfilling of vessel leading to liquor entering vessel vent system and overburden of vent with release of activity to environment	Level control interlocked to feed transfer device Overflow or hardwired trip function on high level	Control vessel level within safe and operable limits and shutdown feeds to vessel normally Provide route for excess feed Shutdown feeds to vessel on high level	See Section 2.1.1 “Vessels” See Section 2.4.5 “Instrument and Control Design” Passive
Backflow of contamination into service lines leading to increased dose uptake by cabinet operator	Lute (loop seal) Isolation valve or line break in cabinet	Provide liquid seal or barrier against backflow of activity into service lines Provide positive automatic or manual isolation of cabinet internals from source of activity	Maintenance Administrative control over isolation valve and position or connection of service line jumper or hose
Loss of confinement (vessel) leading to extra burden on C5 vent system and potential release of activity to the environment	Vessel	Maintain primary confinement.	See Section.2.1.1 “Vessels”
Self-heating of vessel contents due to high C5 content of sludge results in boiling and increased activity burden on vessel vent with potential activity release to the environment	Vessel Cooling water system. Vessel contents temperature control linked to cooling water system	Vessel designed to be self-cooling by heat loss to cell. Remove heat Control heat removal by cooling water system	See Section 2.1.1 “Vessels” See Section 2.5.2 “Cooling Water Systems” See Section 2.4.5 “Instrument and Control Design”

2.8.6. Ion Exchange Columns

2.8.6.1. Purpose

Ion exchange is used in TWRS-P to meet the radionuclide concentration limits for cesium and technetium in the ILAW product by reducing the concentration in the LAW feed.

2.8.6.2. Description

The main process components of the TWRS-P ion exchange system comprise a feed breakpot; four identical ion exchange columns each containing a fixed bed of ion exchange resin suitable for capture of a specific species (cesium and technetium) from the feed liquor; a feed vessel; a collection vessel and transfer pumps for the treated feed stream sulfate removal has a similar system, but has only two columns. The four columns operate in pairs for loading, with a lead column followed by a final (lag) column in series at any given time, while the lead column in the second pair is undergoing regeneration and/or resin replacement. Other equipment includes a make-up vessel and transfer RFDs for regeneration caustic; a make-up vessel and transfer RFDs for caustic rinse; a collection vessel and transfer RFDs for used caustic; a breakpot for the supply of nitric acid, caustic and demineralized water to the columns as required and a steam ejector and breakpot for recycling out-of-specification ion exchange product.

The ion exchange system is in-cell and includes the following operations:

- Capture of target species from the feed to each column
- Regeneration of resin beds using chemical washes and water rinse steps
- Removal of spent resin and replacement by fresh resin

The capture step results in loading of resin beds with target species ions. When a predetermined amount of feed has been processed (or if breakthrough is detected in the effluent from the last column in the pair of columns), the loading operation is switched to a different pair of columns and the loaded column is regenerated.

A regeneration cycle includes displacement of residual feed in the bed by rinsing with caustic solution; a second water rinse; elution of selected specie ions with nitric acid; water rinse and regeneration of resin by caustic wash. The eluted species acid stream is processed in an acid recovery stage. The concentrated specie is stored and the acid recovered and re-used.

Recovered nitric acid at 0.5 M strength is sampled, and when confirmed suitable (i.e., 0.5 M and sufficiently pure) is used to elute resin. Fresh acid at 0.5 M is added to the contents of the recovery acid storage vessels to make up the losses caused by elution reactions which use up some of the acid. This fresh acid is supplied by dilution of 2 M acid with demineralized water (DMW) and the 2 M acid is supplied by dilution of 12.2 M acid with DMW. Each vessel handling acid from 12.2 M to 0.5 M has density measurement for level calibration; flow control on acid and DMW to dilution vessels and temperature indication of diluted acid stream. Zero flow of DMW, low flow alarms and trips and data from density measurements would have to be ignored before 12.2 M acid could find its way into the recovered acid vessels. Then the results of sampling the recovered acid to confirm 0.5 M strength would have to be ignored before 12.2 M acid could ever be in contact with ion exchange resin and cause the resin to degrade.

After a number of loading/regeneration cycles the resin in the lead ion exchanger bed becomes less efficient at removal of its target specie and the spent resin is flushed out of the column as a slurry with water; collected and sent to resin disposal. Fresh resin is slurried into the column by gravity.

All of the loading and regeneration steps are carried out at low pressure by gravity feed from breakpots.

2.8.6.3. Hazardous Situations

The ion exchange columns provide for the reduction in the Cs and Tc quantities in the LAW Product. Excessive concentrations in the LAW glass will give rise to dose impact to the workers. The performance of the ion exchange process is monitored by where possible on line monitors backed up with sampling in product vessels with provision for rework through the process.

Hazardous situations associated with the normal operation of the ion exchange columns include those of confinement associated with all vessels, addressed under vessels that of cross contamination of reagent streams and utilities (process water, cooling water, steam), addressed under the individual systems and those particular to the system for which protection is provided. Known fault conditions against which protection is required are:

1. Overpressurization resulting from resin degradation by radiation generating hydrogen.

2. Overpressurization resulting from resin degradation by thermal effect due to chemical attack leading to volatile generation and possible fire/explosion.

3. Operator dose uptake when adding fresh resin to ion exchange column.

4. Backflow of activity into service lines and cabinets.

5. Backflow of toxic chemicals into service lines and cabinets.

6. Increased dose uptake from LAW product due to inadequate ion exchange performance.

7. Steam generation due to chemical reaction.

   Mixing of chemicals in sufficient strength to cause extensive heat generation and large amounts of steam to challenge the vessel vent system. This did not account for components in the vent system which remove aerosols; the large cooling surface of the vessel vent system and the practicality of mixing strong reagents is low.

8. Criticality

The TWRS Work Plans indicate that the amount of TRU present in the Hanford feed streams that enters TWRS-P process gives no potential for a criticality event to occur. This issue will be tracked until further confirmation that the planned criticality controls are in place to sufficiently rule out this hazard.

Figure 2.8-7. Ion Exchange Columns for Cs and Tc Removal from LAW

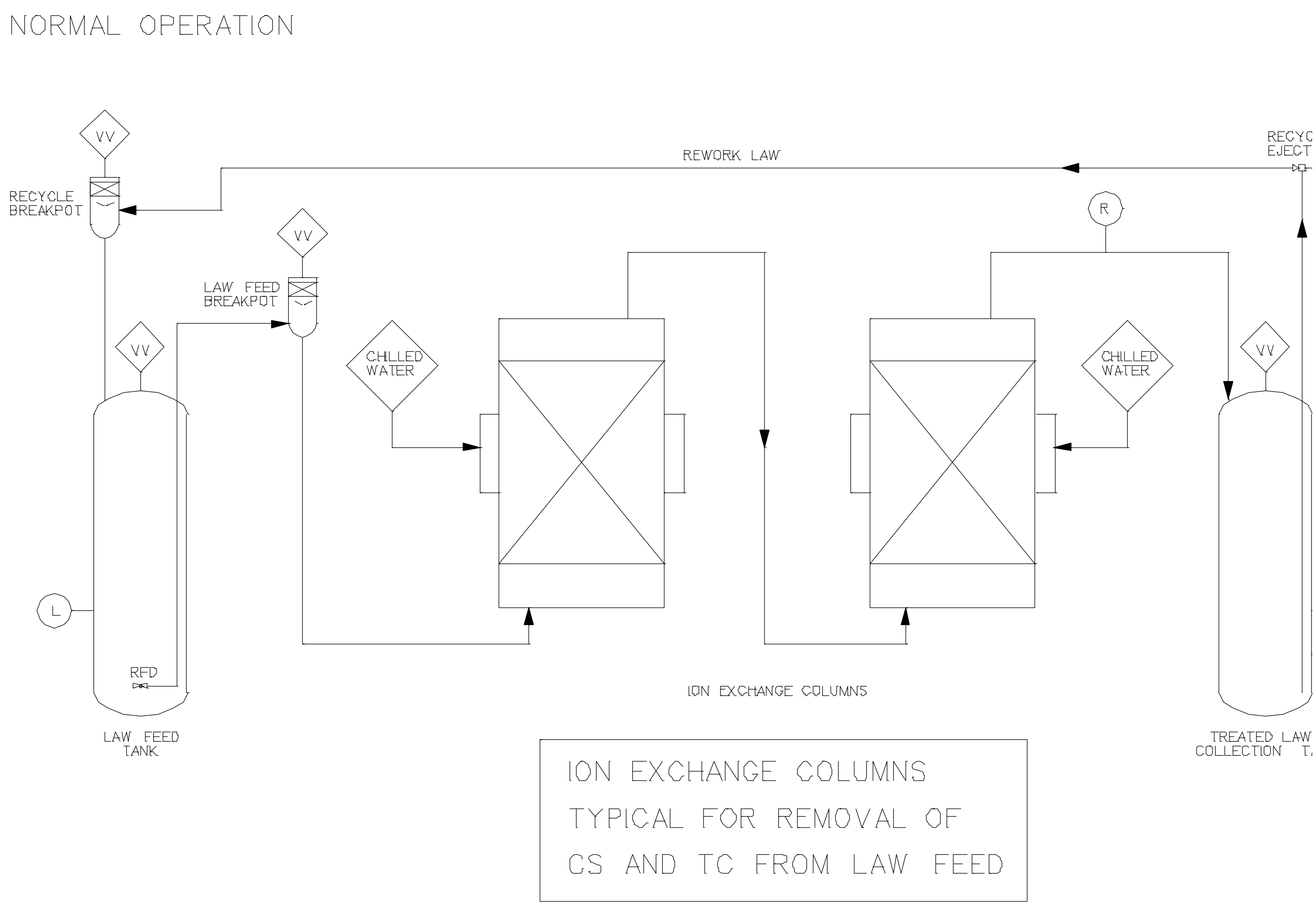

Figure 2.8-8. Ion Exchange Column Resin Elution and Regeneration

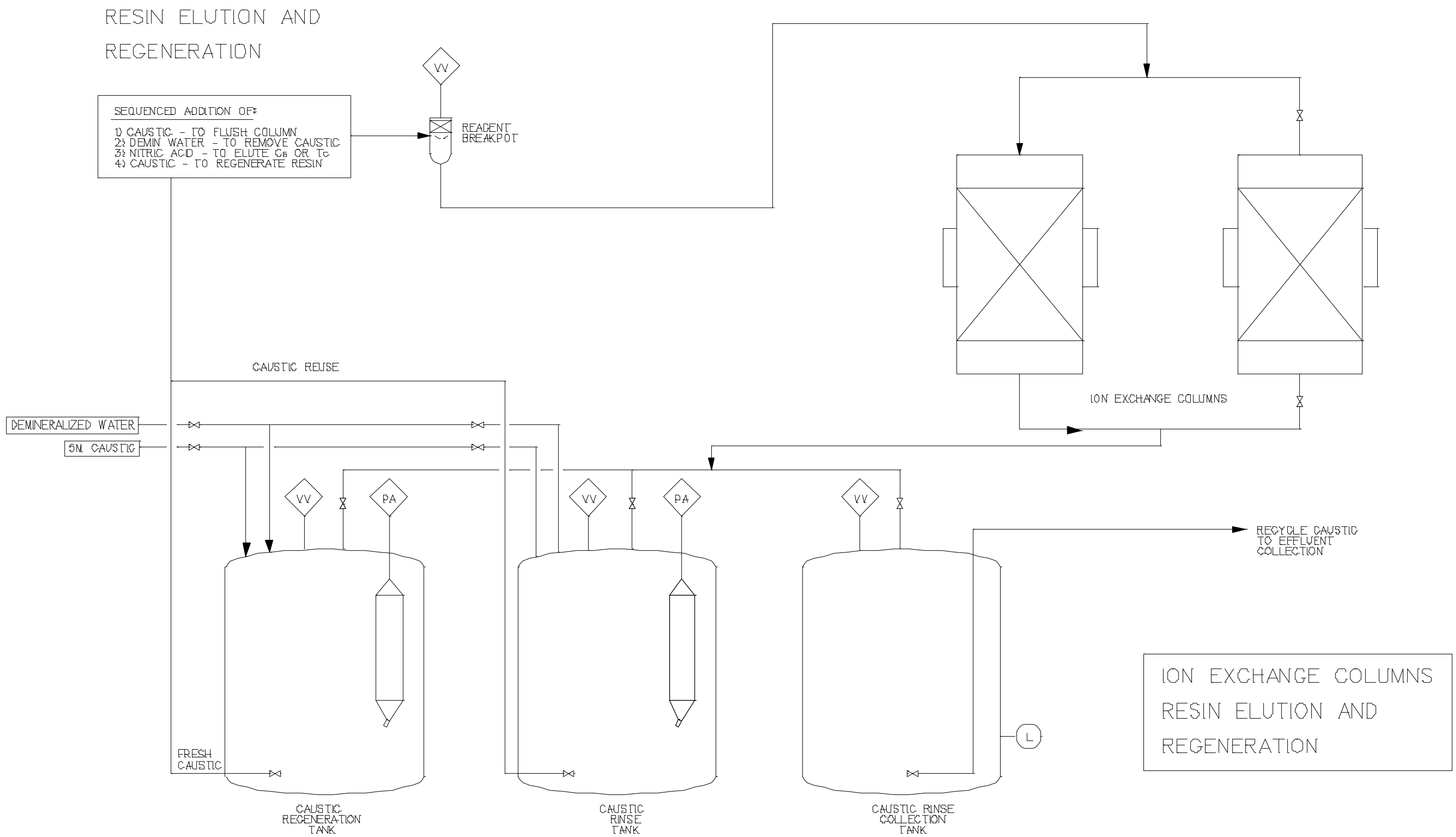

Figure 2.8-9. Ion Exchange Column Resin Addition and Removal

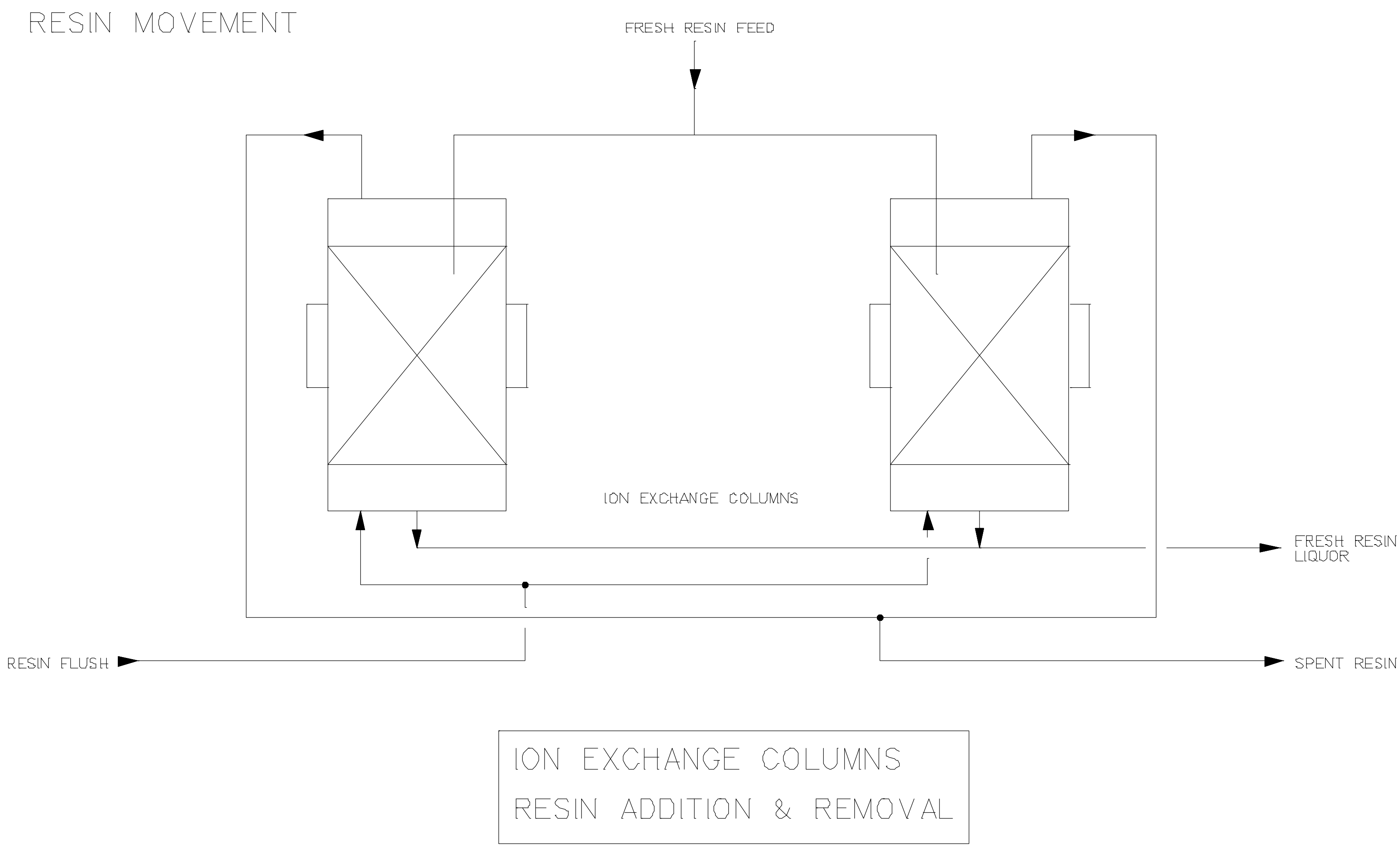

Table 2.8-6. Ion Exchange Columns

Fault	ITS SSC	Safety Function	Design Safety Feature
Overpressuring due to thermal degradation of resin during normal operation	Cooling Water System	Remove heat generated during cesium takeup on resin under normal operation	See Section 2.5.2 “Cooling Water Systems”
	Temperature monitoring	Regulate Cooling water flow Alarm on high temperature	Calibration/maintenance Alarm on failure
	Pressure Relief System	Relieve pressure prior to rupture of column	Inspection procedure Maintenance of relief valve
Overpressuring due to thermal degradation caused by chemical attack on resin producing volatile and flammable gases and possible explosion and fire	Control interlocks Sampling results	Control of dilution sequences for acid; caustic make-up and control of washing, elution and caustic rinse of ion exchange resin so that chemical attack on resin is not possible All system sequential operations are properly interlocked to prevent inadvertent transfers at wrong time or to wrong location	Suitably designed control/interlock system (to be developed) see Section 2.4.5 “Instrument and Control Design Safety Features.” Administrative procedures to log samples and analyses, alarms and movement of acid, caustic and water Commissioning of systems
	Pressure Relief system	Relieve excessive pressure rise in IX column	Inspection procedure Maintenance of relief valve
	Cell	Secondary confinement	See Section 2.1.3 “Cells and Caves
	Pressure measurement in column Delta-P measurement across ion exchange bed	Indicate resin degradation process by any means. Indicative of resin degradation if delta-P drops, the bed has lost resin to be considered in conjunction with temperature and whatever operation is in process at the time	Administrative procedure to select course of corrective action.

Table 2.8-6. Ion Exchange Columns

Fault	ITS SSC	Safety Function	Design Safety Feature
Direct radiation shine on operator when adding fresh resin to active ion exchange column	Suitably designed transfer system for fresh resin slurry fill of active ion exchange column, e.g., joggled line entry to cell from resin make up vessel via suitably designed cabinet	Prevent direct shine path between IX column and fresh resin addition station and operator	To be developed in conjunction with R&D trials on movement of IX resins to and from IX columns
Backflow of radioactivity into service supply cabinets	Lute (loop seals) and means of maintaining liquid seal level Isolation valves Induced air flow	Prevent backflow of radioactive material into inactive feed lines Isolate line from source Prevent back-diffusion of activity by preventing stagnant areas	Maintenance of Lutes (liquid level) Maintenance of valves Isolate direct source but require induced air flow. Induced air flow to vessel vent or positive air purge
Blockage of IX column outlet leading to backup of reagents into reagent pipework and into chemicals supply cabinet	Suitably designed resin removal system for bulk solids and resin fines	Ensure removal system, e.g., high pressure water slurrying of IX resin in column and subsequent drain to collection vessel, is effective in removing all resin solids from the IX column	To be developed in conjunction with R&D
Failure of IX performance giving rise to the potential for increased dose to workers handling the LAW glass product.	Sampling	Sampling and hold up of product from the Cs and Tc IX columns.	Administrative controls to ensure that a sample is taken and that the forward transfer of liquid to the LAW Melters is only carried out on receipt of an acceptable sample result. Where sufficient sensitivity can be obtained on-line Cs and Tc breakthrough monitors will be provided after the columns to alarm on breakthrough from the lead column. The lag column will then provide a further barrier to the breakthrough of Cs and Tc.

2.8.7. Nitric Acid Recovery

2.8.7.1. Purpose

The purpose of this system is to reduce the volume of the eluant stream from the ion exchange processes and to recover as much as possible of the nitric acid from these streams for reuse. Nitric acid recovery is used in conjunction with the cesium and technetium LAW ion exchange columns.

2.8.7.2. Description

The main process components of the TWRS-P nitric acid recovery system comprise the evaporator, rectifier column, rectifier overhead condenser, after-condenser, recovered acid tank and eluant storage vessel. Other equipment include the receipt vessels, constant volume feeder, and transfer RFDs. Eluant from ion exchange columns, with nitric acid and cesium ion being the main constituents of concern, is collected and fed to a steam-jacketed evaporator vessel via a constant-volume feeder. The concentrated nitric acid cesium/technetium from the evaporator is transferred to a concentrate storage vessel where it is stored for feeding to the HLW melter system.

Acid and water vapors from the evaporator pass through a refluxed rectifier column where the nitric acid is condensed and thereby recovered for reuse as eluant. Water vapor from the top of the rectifier column is condensed under vacuum in tube-and-shell heat exchangers with cooling water. This water that is condensed is acidic, and is transferred to the Condensate/Plant Wash and Drains system.

2.8.7.3. Hazardous Situations

The normal operation of the nitric acid recovery system is to provide for the volume reduction and recovery of nitric acid for re-use. The failure of this unit operation to meet the process design specification (i.e., insufficient or excessive evaporation; the latter, however, requires more detailed impact analysis) does not result in the generation of a hazardous situation. The hazardous situations arise from the operation required to carry out the unit operation.

Hazardous situations associated with the normal operation of the nitric acid recovery system include those of confinement associated with all vessels, addressed under vessels; that of cross contamination of reagent streams and utilities (process water, cooling water and steam), addressed under the individual systems; and those particular to the system for which protection is provided. Known fault conditions against which protection is required are:

- Loss of Cooling cesium/technetium storage vessel potential for self boiling/generation of active vapors
- Loss of cooling water to overhead condenser causes loss of reflux to column and potential for acid vapors in overheads and vessel vent system
- Loss of cooling water to acid storage vessels causes potential for acid vapors in vessel vent system
- Challenge to HEPA Filters from evaporator overheads
- Over filling of vessels—see Section 2.1.1 “Vessels”

Figure 2.8-10. Nitric Acid Recovery

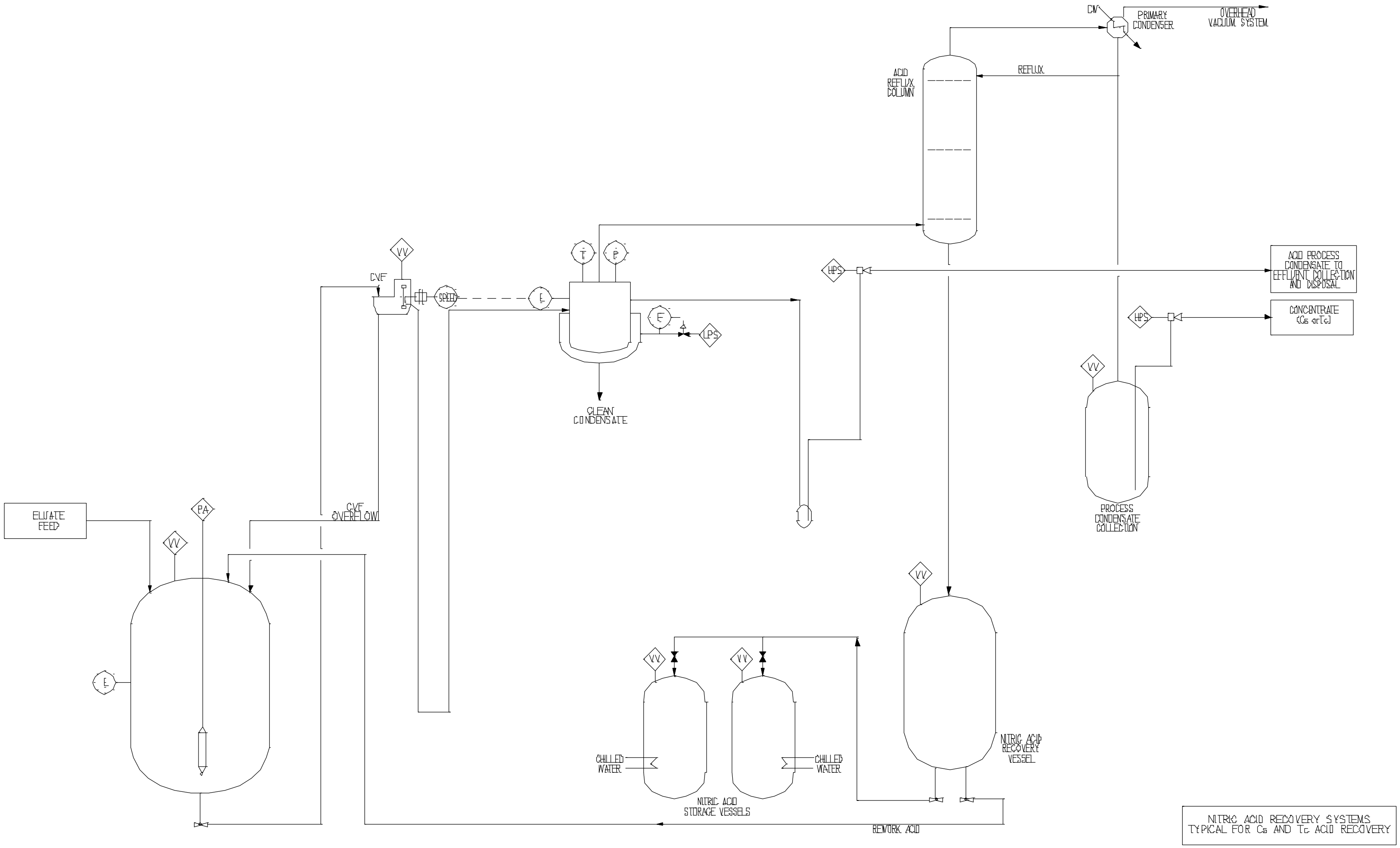

Table 2.8-7. Nitric Acid Recovery

Fault	ITS SSC	Safety Function	Design Safety Feature
Loss of cooling in cesium/technetium storage vessel and potential for self boiling/generation of active vapors	Vessel	Vessel designed to be self-cooling by heat loss to cell	See Section 2.1.1 "Vessels"
	Cooling Water System	Prevent boiling of vessel contents	Redundant coil system with independent supply See Section 2.5.2 "Cooling Water Systems"
	Temperature measurement	Notification of high temperatures	Alarmed Maintenance/Calibration
Loss of cooling water to overhead condenser causes loss of reflux to column and potential for acid vapors in overheads and vessel vent system	Cooling Water System Cooling water interlocks	Condense Overheads [water vapor] Shutdown vacuum ejectors and evaporator on loss of cooling	See Section 2.5.2 "Cooling Water Systems" Steam ejectors and evaporator shutdown on loss of cooling water
Loss of cooling water to acid storage vessels causes potential for acid vapors in vessel vent system	Cooling Water System	Cool Vessel	Redundancy of cooling water system See Section 2.5.2 :Cooling Water Systems"
Challenge to HEPA filters in offgas system -increased activity and physical impact	Cooling Water System HEME and Water scrubber component in off-gas treatment	Prevent excessive temperature leading to excessive wet vapor entering vent system from vessel Remove gross active aerosols hot vapors from offgas stream to prevent reducing HEPA efficiency or useful life	Redundant coil system with independent supply see Cooling water system

2.8.8. Ultrafiltration

2.8.8.1. Purpose

Ultrafiltration will be used to remove entrained solids from the low activity waste (LAW) feed and complexed strontium and transuranic elements (TRU) from the Envelope C feed. The entrained solids are removed in order to protect downstream ion exchange beds and to reduce the overall radionuclide loading in the facility and in the final LAW glass product. To meet immobilized LAW (ILAW) glass specifications, the complexed strontium and transuranic elements (TRU) from the Envelope C feed will be removed and routed to high level waste (HLW) vitrification.

Ultrafiltration will also be used in the HLW pretreatment process and to dewater HLW feed prior to vitrification, as discussed in the HLW Receipt and Pretreatment System.

2.8.8.2. Description

The main process components of the TWRS-P ultrafiltration system comprise an ultrafilter, ultrafilter cooler (heat exchangers), recirculation pump, permeate and entrained solids hold vessels, feed vessels, breakpots, pulse pots, and flow control valves.

The ultrafiltration process consists of two parallel ultrafilter circuits. During operation, only one circuit will be online at one time. Feed will be routed from a receipt vessel to the ultrafiltration feed tanks. The size of the transfer will be limited to the size of the feed vessel or to one days worth of feed after treatment. From the feed tanks, the feed will be pumped through the ultrafilter unit which separates the liquid (permeate) from the entrained solids. Permeate from the ultrafilter will collect in the permeate collection vessel and concentrated solids will collect in the ultrafilter feed vessel after passing through a heat exchanger. From the feed vessel the solids are routed to storage or back through the ultrafiltration process.

2.8.8.3. Hazardous Situations

The ultrafiltration unit operation provide for the removal of the solids in the feed in order to protect the IX columns and to reduce the Sr and TRU (for envelope C type wastes) in the LAW Product. Excessive concentrations of Sr and TRU in the LAW glass will give rise to dose impact to the workers. The performance of the ultrafiltration process is monitored by sampling in product vessels with provision for re-work through the process.

The hazardous situations leading to potential hazards arising in ultra filtration are:

- Leakage of high pressure active fluids from the ultra filtration circuits
-
- The potential to cross-contaminate utilities via leaks in the heat exchanger used in both the LAW ultra filtration (cooling water)
-
- The HLW ultra filtration (LP steam) circuits.

Figure 2.8-11. LAW Ultrafiltration

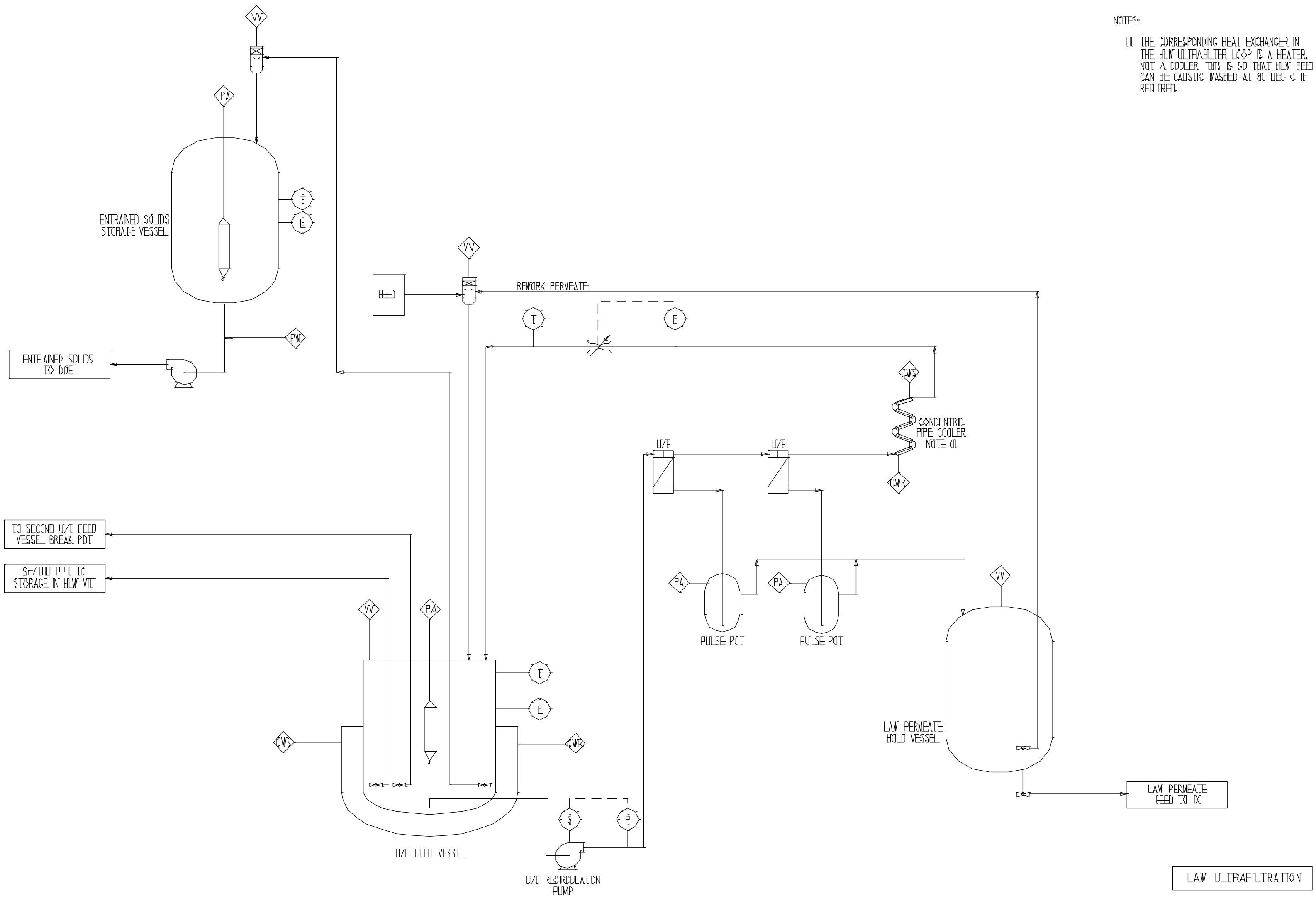

Table 2.8-8. Ultrafiltration

Fault	Important to Safety SSC	Safety Function	Design Safety Feature
Failure of U/F pressure boundary challenges cell ventilation system	U/F system	Provide pressure boundary	Selection of material and method of construction. Confinement issues are addressed separately in the Confinement section under ultra filtration All welded pipe construction and double seal arrangements in U/F housing
Cross contamination in heat exchanger	Tubes, valves and gamma detector	Prevent cross-contamination of services	See Section 2.5.2 “Cooling Water Systems “
Failure of ultrafiltration performance giving rise to the potential for increased dose to workers handling the LAW glass product.	Sampling	Sampling and hold up of product from the Sr/TRU separation	Administrative controls to ensure that a sample is taken and that the forward transfer of liquid to the LAW Melters is only carried out on receipt of an acceptable sample result.

References

M.N. Hutcheson, H.K. Fauske, R.E. Henry and T.J. Marciniak, 1983, *Assessment of the potential and Consequences of a Hypothetical Steam Explosion in the Defense Waste Processing Facility*, FAI/83-8, Fauske & Associates, Burr Ridge, IL, February 1983.